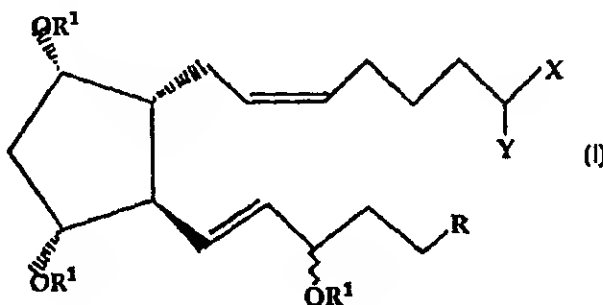




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(21) International Application Number: PCT/US98/24481 (22) International Filing Date: 17 November 1998 (17.11.98) (30) Priority Data: 08/974,067 19 November 1997 (19.11.97) US (71) Applicant: ALLERGAN SALES, INC. [US/US]; 2525 Dupont Drive, Irvine, CA 92612 (US). (72) Inventor: BURK, Robert, M.; 1337 Cerritos Avenue, Laguna Beach, CA 92651 (US). (74) Agents: BARAN, Robert, J. et al.; Allergan Sales, Inc., 2525 Dupont Drive, Irvine, CA 92612 (US).		(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, GM, HR, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).  Published With international search report.

(54) Title: **CYCLOPENTANE HEPTAN(ENE)OIC ACID, 2-HETEROARYLALKENYL DERIVATIVES AS THERAPEUTIC AGENTS**

## (57) Abstract

The invention relates to the use of derivatives of F-type prostaglandins as ocular hypotensives. The compounds used in accordance with the invention are represented by formula (I), wherein wavy line attachments indicate either the alpha ( $\alpha$ ) or beta ( $\beta$ ) configuration; hatched segments indicate  $\alpha$  configuration; the solid triangle is used to indicate  $\beta$  configuration; dashed bonds represent a double bond, or a single bond; R is a substituted heteroaryl radical having at least two pendant substituents selected from the group consisting of C1 to C6 alkyl; halogen; trifluoromethyl; COR<sup>1</sup>; COCF<sub>3</sub>; SO<sub>2</sub>NR<sup>1</sup>; NO<sub>2</sub> and CN or at least one cyano group; R<sup>1</sup> is hydrogen or a lower alkyl radical having up to six carbon atoms, X is selected from the group consisting of -OR<sup>1</sup> and -N(R<sup>1</sup>)<sub>2</sub>; Y is -O or represents 2 hydrogen radicals and the 9, 11 or 15 lower alkyl esters thereof; provided, however, when said heteroaryl radical is a dichlorothieryl radical, the compound is not a 1-carboxylic acid or amide thereof. Certain of the compounds represented by Formula (I) are novel and comprise another aspect of the present invention.

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CYCLOPENTANE HEPTAN(ENE)OIC ACID, 2-  
HETEROARYLALKENYL DERIVATIVES AS THERAPEUTIC  
AGENTS

5

Background of the Invention

1. Field of the Invention

10           The present invention relates to cyclopentane heptanoic acid, 2  
heteroarylalkenyl derivatives which may be substituted in the 1-position  
with hydroxyl, alkyloxy, amino and amido groups, e.g. 1-OH  
cyclopentane heptanoic acid, 2 heteroarylalkenyl derivatives. These  
compounds are potent ocular hypotensive and are particularly suited for  
15           the management of glaucoma.

2. Description of Related Art

20           Ocular hypotensive agents are useful in the treatment of a number  
of various ocular hypertensive conditions, such as post-surgical and post-  
laser trabeculectomy ocular hypertensive episodes, glaucoma, and as  
presurgical adjuncts.

25           Glaucoma is a disease of the eye characterized by increased  
intraocular pressure. On the basis of its etiology, glaucoma has been  
classified as primary or secondary. For example, primary glaucoma in  
adults (congenital glaucoma) may be either open-angle or acute or  
chronic angle-closure. Secondary glaucoma results from pre-existing  
ocular diseases such as uveitis, intraocular tumor or an enlarged cataract.

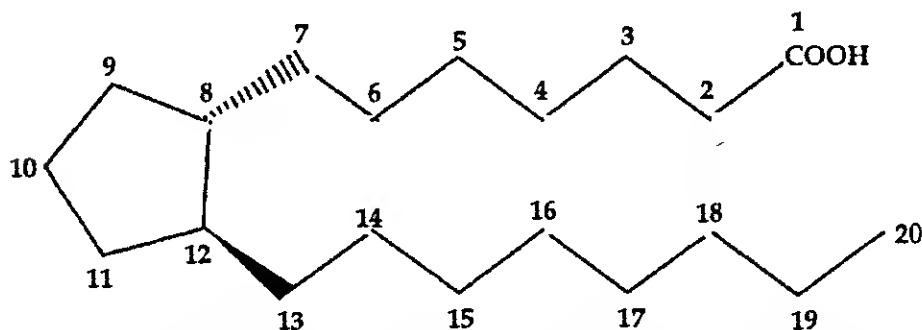
30           The underlying causes of primary glaucoma are not yet known.  
The increased intraocular tension is due to the obstruction of aqueous  
humor outflow. In chronic open-angle glaucoma, the anterior chamber  
and its anatomic structures appear normal, but drainage of the aqueous  
humor is impeded. In acute or chronic angle-closure angle-closure  
glaucoma, the anterior chamber is shallow, the filtration angle is  
35           narrowed, and the iris may obstruct the trabecular meshwork at the  
entrance of the canal of Schlemm. Dilation of the pupil may push the root

of the iris forward against the angle, and may produce pupillary block and thus precipitate an acute attack. Eyes with narrow anterior chamber angles are predisposed to acute angle-closure glaucoma attacks of various degrees of severity.

5        Secondary glaucoma is caused by any interference with the flow of aqueous humor from the posterior chamber into the anterior chamber and subsequently, into the canal of Schlemm. Inflammatory disease of the anterior segment may prevent aqueous escape by causing complete posterior synechia in iris bombe, and may plug the drainage channel with  
10        exudates. Other common causes are intraocular tumors, enlarged cataracts, central retinal vein occlusion, trauma to the eye, operative procedures and intraocular hemorrhage.

      Considering all types together, glaucoma occurs in about 2% of all persons over the age of 40 and may be asymptotic for years before  
15        progressing to rapid loss of vision. In cases where surgery is not indicated, topical  $\beta$ -adrenoreceptor antagonists have traditionally been the drugs of choice for treating glaucoma.

      Certain eicosanoids and their derivatives have been reported to possess ocular hypotensive activity, and have been recommended for use  
20        in glaucoma management. Eicosanoids and derivatives include numerous biologically important compounds such as prostaglandins and their derivatives. Prostaglandins can be described as derivatives of prostanoic acid which have the following structural formula:



      Various types of prostaglandins are known, depending on the structure and substituents carried on the alicyclic ring of the prostanoic acid skeleton. Further classification is based on the number of

unsaturated bonds in the side chain indicated by numerical subscripts after the generic type of prostaglandin [e.g. prostaglandin E<sub>1</sub> (PGE<sub>1</sub>), prostaglandin E<sub>2</sub> (PGE<sub>2</sub>)], and on the configuration of the substituents on the alicyclic ring indicated by  $\alpha$  or  $\beta$  [e.g. prostaglandin F<sub>2</sub> $\alpha$  (PGF<sub>2</sub> $\alpha$ )].

5 Prostaglandins were earlier regarded as potent ocular hypertensives, however, evidence accumulated in the last decade shows that some prostaglandins are highly effective ocular hypotensive agents, and are ideally suited for the long-term medical management of glaucoma (see, for example, Bito, L.Z. Biological Protection with Prostaglandins, Cohen, M.M., ed., Boca Raton, Fla, CRC Press Inc., 1985, pp. 231-252; and Bito, L.Z., Applied Pharmacology in the Medical Treatment of Glaucomas Drance, S.M. and Neufeld, A.H. eds., New York, Grune & Stratton, 1984, pp. 477-505. Such prostaglandins include PGF<sub>2</sub> $\alpha$ , PGF<sub>1</sub> $\alpha$ , PGE<sub>2</sub>, and certain lipid-soluble esters, such as C<sub>1</sub> to C<sub>2</sub> alkyl  
10  
15 esters, e.g. 1-isopropyl ester, of such compounds.

Although the precise mechanism is not yet known experimental results indicate that the prostaglandin-induced reduction in intraocular pressure results from increased uveoscleral outflow [Nilsson et.al., Invest. Ophthalmol. Vis. Sci. (suppl), 284 (1987)].

20 The isopropyl ester of PGF<sub>2</sub> $\alpha$  has been shown to have significantly greater hypotensive potency than the parent compound, presumably as a result of its more effective penetration through the cornea. In 1987, this compound was described as "the most potent ocular hypotensive agent ever reported" [see, for example, Bito, L.Z., Arch. Ophthalmol. 105, 1036 (1987), and Siebold et.al., Prodrug 5 3 (1989)].

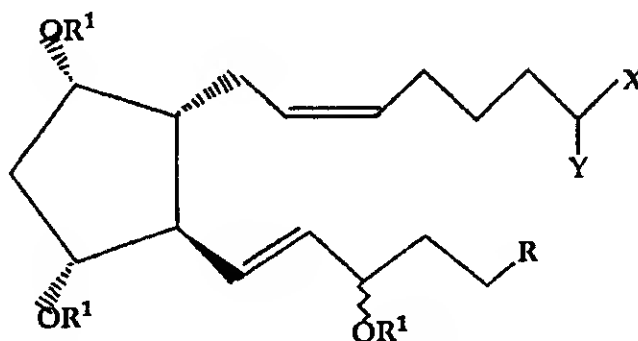
Whereas prostaglandins appear to be devoid of significant intraocular side effects, ocular surface (conjunctival) hyperemia and foreign-body sensation have been consistently associated with the topical ocular use of such compounds, in particular PGF<sub>2</sub> $\alpha$  and its prodrugs, e.g.,  
30 its 1-isopropyl ester, in humans. The clinical potentials of prostaglandins in the management of conditions associated with increased ocular pressure, e.g. glaucoma are greatly limited by these side effects.

In a series of co-pending United States patent applications assigned to Allergan, Inc. prostaglandin esters with increased ocular  
35 hypotensive activity accompanied with no or substantially reduced side-

effects are disclosed. The co-pending USSN 596,430 (filed 10 October 1990), relates to certain 11-acyl-prostaglandins, such as 11-pivaloyl, 11-acetyl, 11-isobutyryl, 11-valeryl, and 11-isovaleryl PGF<sub>2</sub> $\alpha$ . Intraocular pressure reducing 15-acyl prostaglandins are disclosed in the co-pending application USSN 175,476 (filed 29 December 1993). Similarly, 11,15- 9,15 and 9,11-diester of prostaglandins, for example 11,15-dipivaloyl PGF<sub>2</sub> $\alpha$  are known to have ocular hypotensive activity. See the co-pending patent applications USSN Nos. 385,645 (filed 07 July 1989, now U.S. Patent 4,994,274), 584,370 (filed 18 September 1990, now U.S. Patent 5,028,624) and 585,284 (filed 18 September 1990, now U.S. Patent 5,034,413). The disclosures of all of these patent applications are hereby expressly incorporated by reference in their entirety. This patent application is also related to U.S. Patent Application Serial No. 08/726,921, which was filed on October 7, 1996 in the name of Burk, which is a File Wrapper Continuation of U.S. Patent Application Serial No. 08/443,992 which was filed on May 18, 1995 in the name of Burk, both of which patent applications are expressly incorporated by reference in their entirety.

### Summary of the Invention

The present invention concerns a method of treating ocular hypertension which comprises administering to a mammal having ocular hypertension a therapeutically effective amount of a compound of formula I



wherein the hatched segments represent  $\alpha$  bonds, the solid triangle represents a  $\beta$  bond, the wavy segment represents  $\alpha$  or  $\beta$  bond, dashed

lines represent a double bond or a single bond, R is a substituted heteroaryl radical having at least two pendant substituents selected from the group consisting of lower alkyl, e.g. C<sub>1</sub> to C<sub>6</sub> alkyl; halogen; trifluoromethyl; COR<sup>1</sup>, COCF<sub>3</sub>; SO<sub>2</sub>NR<sup>1</sup>; NO<sub>2</sub>; CN or at least one cyano substituent, i.e. CN; R<sup>1</sup> is hydrogen or a lower alkyl radical having up to six carbon atoms, X is selected from the group consisting of -OR<sup>1</sup> and -N(R<sup>1</sup>)<sub>2</sub>, Y is = O or represents 2 hydrogen radicals, and the 9, 11, or 15 lower alkyl esters thereof; provided, however, when said heteroaryl radical is a dichloro thienyl radical, said compound is not a 1-carboxylic acid or amide thereof. In a further aspect, the present invention relates to an ophthalmic solution comprising a therapeutically effective amount of a compound of formula (I), wherein the symbols have the above meanings, or a pharmaceutically acceptable salt thereof, in admixture with a non-toxic, ophthalmically acceptable liquid vehicle, packaged in a container suitable for metered application. In particular, the substituents on the heteroaryl radical may be selected from the group consisting of lower alkyl, e.g. C<sub>1</sub> to C<sub>6</sub> alkyl; halogen, e.g. fluoro, chloro and bromo; trifluoromethyl (CF<sub>3</sub>); COR<sup>1</sup>, e.g. COCH<sub>3</sub>; COCF<sub>3</sub>; SO<sub>2</sub>NR<sup>1</sup>, e.g. SO<sub>2</sub>NH<sub>2</sub>; NO<sub>2</sub>; CN; etc.

In a still further aspect, the present invention relates to a pharmaceutical product, comprising  
a container adapted to dispense its contents in a metered form; and

an ophthalmic solution therein, as hereinabove defined.

Finally, certain of the compounds represented by the above formula, disclosed below and utilized in the method of the present invention are novel and unobvious.

### Brief Description of the Drawing Figures

Figure 1 is a schematic of the chemical synthesis of certain 1-carboxylic acid compounds of the invention specifically disclosed in Example 5(a)-(e) below.

6

Figure 2 is a schematic of the chemical synthesis of certain 1-carboxylic acid or 1-amido compounds of the invention specifically disclosed in Example 5(f) and 11(f), below.

5 Figure 3 is a schematic of the chemical synthesis of certain 1-amido compounds of the invention specifically disclosed in Examples 11(a)-(e), below.

10 Figure 4 is a schematic of the chemical synthesis of certain 1-amido compounds of the invention as specifically disclosed in Examples 11 (g)-(j), below.

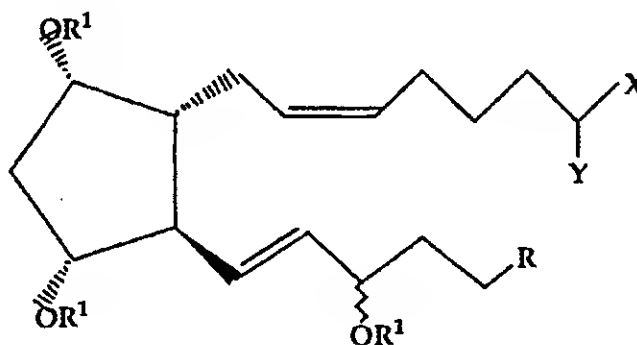
15 Figure 5 is a schematic of the chemical synthesis of 1-isopropylester compounds of the invention as specifically disclosed in Examples 12 (a)-(b) and 12(k)-(l), below.

### Detailed Description of the Invention

20

The present invention relates to the use of nonacidic cyclopentane heptan(ene)oic acid, 2-heteroaryl alkenyl derivatives as therapeutic agents, e.g. as ocular hypotensives. The compounds used in accordance with the present invention are encompassed by the following structural formula I:

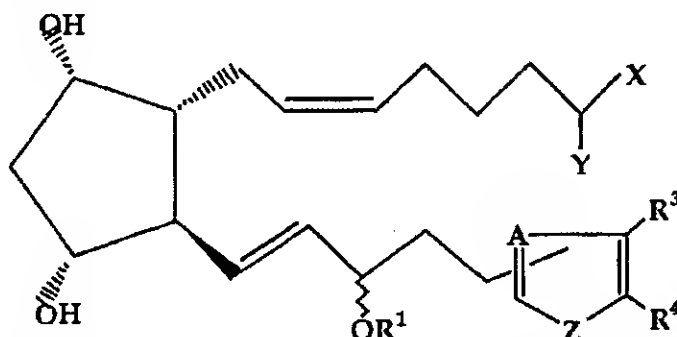
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7

wherein the substituents and symbols are as hereinabove defined. The dotted lines on bonds between carbons 5 and 6 (C-5) and carbons 13 and 14 (C-13) indicate a single or double bond. If two solid lines are used at C-5, or C-13, it indicates a specific configuration for that double bond. Hatched lines used at position C-8, C-9 and C-11 indicate the  $\alpha$  configuration. A triangle at position C-12 represents  $\beta$  orientation. A preferred group of the compounds of the present invention includes compounds that have the following structural formula II:

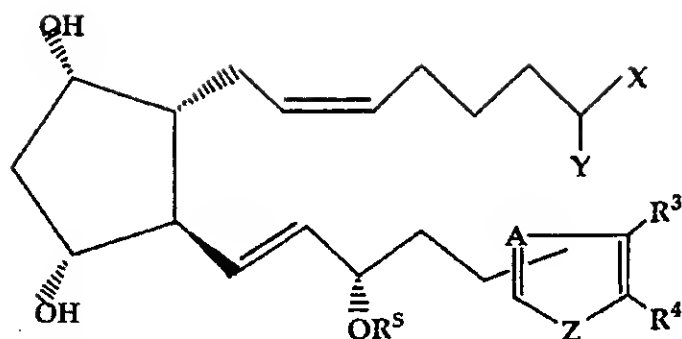


wherein Z is selected from the group consisting of O and S; A is selected from the group consisting of C or CR<sup>2</sup>; R<sup>2</sup>, R<sup>3</sup> and R<sup>4</sup> are selected from the group consisting of hydrogen, cyano, halogen and lower alkyl having from 1 to 6 carbon atoms. Preferably, when X is -N(R<sup>1</sup>)<sub>2</sub>, Y is = O. More preferably, at least one of R<sup>2</sup>, R<sup>3</sup> or R<sup>4</sup> are independently selected from the group consisting of chloro, bromo, iodo, cyano and methyl.

In one aspect of the invention, at least one of R<sup>2</sup>, R<sup>3</sup> or R<sup>4</sup> is bromo, and at least one other of R<sup>2</sup>, R<sup>3</sup> or R<sup>4</sup> is bromo or methyl, or R<sup>2</sup>, R<sup>3</sup> and R<sup>4</sup> are chloro, or at least one other of R<sup>2</sup>, R<sup>3</sup> or R<sup>4</sup> is methyl and at least one other of R<sup>2</sup>, R<sup>3</sup> and R<sup>4</sup> is bromo or iodo. In another aspect of this invention, R<sup>2</sup> is cyano and R<sup>3</sup> and R<sup>4</sup> are hydrogen.

Another preferred group includes compounds having the formula III:

8



In the above formulae, the substituents and symbols are as hereinabove defined and  $R^5$  is hydrogen.

5 The above compounds of the present invention may be prepared by methods that are known in the art or according to the working examples below. The compounds, below, are especially preferred representative of the compounds of the present invention.

10 7-[3 $\alpha$ , 5 $\alpha$ -Dihydroxy-2-(3 $\alpha$ -hydroxy-5-(5-(2-cyano)thienyl)-1E-pentenyl)cyclopentyl]-5Z-heptenoic acid (5a)

7-[3 $\alpha$ , 5 $\alpha$ -Dihydroxy-2-(3 $\alpha$ -hydroxy-5-(5-(2,3,4-trichloro)thienyl)-1E-pentenyl)cyclopentyl]-5Z-heptenoic acid (5b)

15 7-[3 $\alpha$ , 5 $\alpha$ -Dihydroxy-2-(3 $\alpha$ -hydroxy-5-(5-(2,3-dichloro)thienyl)-1E-pentenyl)cyclopentyl]-5Z-heptenoic acid (5c)

20 7-[3 $\alpha$ , 5 $\alpha$ -Dihydroxy-2-(3 $\alpha$ -hydroxy-5-(5-(2-iodo-4-methyl)thienyl)-1E-pentenyl)cyclopentyl]-5Z-heptenoic acid (5d)

7-[3 $\alpha$ , 5 $\alpha$ -Dihydroxy-2-(3 $\alpha$ -hydroxy-5-(4-(3-bromo-2,5-dimethyl)thienyl)-1E-pentenyl)cyclopentyl]-5Z-heptenoic acid (5e)

9

7-[3 $\alpha$ , 5 $\alpha$ -Dihydroxy-2-(3 $\alpha$ -hydroxy-5-(3-(2,5-dichloro)thienyl)pentyl)-  
cyclopentyl]-5Z-heptenoic acid (5f)

5 7-[3 $\alpha$ , 5 $\alpha$ -Dihydroxy-2-(3 $\alpha$ -hydroxy-5-(5-(2-cyano)thienyl)-1E-  
pentenyl)cyclopentyl]-5Z-heptenamide (11a)

7-[3 $\alpha$ , 5 $\alpha$ -Dihydroxy-2-(3 $\alpha$ -hydroxy-5-(5-(2,3,4-trichloro)thienyl)-1E-  
pentenyl)cyclopentyl]-5Z-heptenamide (11b)

10 7-[3 $\alpha$ , 5 $\alpha$ -Dihydroxy-2-(3 $\alpha$ -hydroxy-5-(5-(2,3-dichloro)thienyl)-1E-  
pentenyl)cyclopentyl]-5Z-heptenamide (11c)

7-[3 $\alpha$ , 5 $\alpha$ -Dihydroxy-2-(3 $\alpha$ -hydroxy-5-(5-(2-iodo-4-methyl)thienyl)-1E-  
pentenyl)cyclopentyl]-5Z-heptenamide (11d)

15

7-[3 $\alpha$ , 5 $\alpha$ -Dihydroxy-2-(3 $\alpha$ -hydroxy-5-(3-(2,5-dichloro)thienyl)-  
pentenyl)cyclopentyl]-5Z-heptenamide (11f)

20 N-2-Hydroxyethyl 7-[3 $\alpha$ , 5 $\alpha$ -dihydroxy-2-(3 $\alpha$ -hydroxy-5-(5-(3-bromo-2-  
methyl)thienyl)-1E-pentenyl)cyclopentyl]-5Z-heptenamide (11g)

N-Ethyl 7-[3 $\alpha$ , 5 $\alpha$ -dihydroxy-2-(3 $\alpha$ -hydroxy-5-(5-(3-bromo-2-  
methyl)thienyl)-1E-pentenyl)cyclopentyl]-5Z-heptenamide (11h)

25 N-2-Hydroxyethyl 7-[3 $\alpha$ , 5 $\alpha$ -dihydroxy-2-(3 $\alpha$ -hydroxy-5-(3-(2,5-  
dibromo)-thienyl)-1E-pentenyl)cyclopentyl]-5Z-heptenamide (11i)

N-Ethyl 7-[3 $\alpha$ , 5 $\alpha$ -dihydroxy-2-(3 $\alpha$ -hydroxy-5-(3-(2,5-dibromo)-thienyl)-  
1E-pentenyl)cyclopentyl]-5Z-heptenamide (11j)

30

Isopropyl 7-[3 $\alpha$ , 5 $\alpha$ -Dihydroxy-2-(3 $\alpha$ -hydroxy-5-(5-(2-cyano)thienyl)-1E-pentenyl)cyclopentyl]-5Z-heptenoate (12a)

5 Isopropyl 7-[3 $\alpha$ , 5 $\alpha$ -Dihydroxy-2-(3 $\alpha$ -hydroxy-5-(5-(2,3,4-trichloro)-thienyl)-1E-pentenyl)cyclopentyl]-5Z-heptenoate (12b)

Isopropyl 7-[3 $\alpha$ , 5 $\alpha$ -Dihydroxy-2-(3 $\alpha$ -hydroxy-5-(5-(3-bromo-2-methyl)-thienyl)-1E-pentenyl)cyclopentyl]-5Z-heptenoate (12k)

10 Isopropyl 7-[3 $\alpha$ , 5 $\alpha$ -Dihydroxy-2-(3 $\alpha$ -hydroxy-5-(3-(2,5-dibromo)-thienyl)-1E-pentenyl)cyclopentyl]-5Z-heptenoate (12l)

15 A pharmaceutically acceptable salt is any salt which retains the activity of the parent compound and does not impart any deleterious or undesirable effect on the subject to whom it is administered and in the context in which it is administered. Of particular interest are salts formed with inorganic ions, such as sodium, potassium, calcium, magnesium and zinc.

20 Pharmaceutical compositions may be prepared by combining a therapeutically effective amount of at least one compound according to the present invention, or a pharmaceutically acceptable acid addition salt thereof, as an active ingredient, with conventional ophthalmically acceptable pharmaceutical excipients, and by preparation of unit dosage forms suitable for topical ocular use. The therapeutically efficient amount  
25 typically is between about 0.0001 and about 5% (w/v), preferably about 0.001 to about 1.0% (w/v) in liquid formulations.

30 For ophthalmic application, preferably solutions are prepared using a physiological saline solution as a major vehicle. The pH of such ophthalmic solutions should preferably be maintained between 6.5 and 7.2 with an appropriate buffer system. The formulations may also contain conventional, pharmaceutically acceptable preservatives, stabilizers and surfactants.

Preferred preservatives that may be used in the pharmaceutical compositions of the present invention include, but are not limited to, benzalkonium chloride, chlorobutanol, thimerosal, phenylmercuric acetate and phenylmercuric nitrate. A preferred surfactant is, for example, Tween 80. Likewise, various preferred vehicles may be used in the ophthalmic preparations of the present invention. These vehicles include, but are not limited to, polyvinyl alcohol, povidone, hydroxypropyl methyl cellulose, poloxamers, carboxymethyl cellulose, hydroxyethyl cellulose and purified water.

Tonicity adjustors may be added as needed or convenient. They include, but are not limited to, salts, particularly sodium chloride, potassium chloride, mannitol and glycerin, or any other suitable ophthalmically acceptable tonicity adjustor.

Various buffers and means for adjusting pH may be used so long as the resulting preparation is ophthalmically acceptable. Accordingly, buffers include acetate buffers, citrate buffers, phosphate buffers and borate buffers. Acids or bases may be used to adjust the pH of these formulations as needed.

In a similar vein, an ophthalmically acceptable antioxidant for use in the present invention includes, but is not limited to, sodium metabisulfite, sodium thiosulfate, acetylcysteine, butylated hydroxyanisole and butylated hydroxytoluene.

Other excipient components which may be included in the ophthalmic preparations are chelating agents. The preferred chelating agent is edentate disodium, although other chelating agents may also be used in place or in conjunction with it.

The ingredients are usually used in the following amounts:

	<u>Ingredient</u>	<u>Amount (% w/v)</u>
30	active ingredient	about 0.001-5
	preservative	0-0.10
	vehicle	0-40
	tonicity adjustor	1-10
	buffer	0.01-10
35	pH adjustor	q.s. pH 4.5-7.5
	antioxidant	as needed
	surfactant	as needed
	purified water	as needed to make 100%

The actual dose of the active compounds of the present invention depends on the specific compound, and on the condition to be treated; the selection of the appropriate dose is well within the knowledge of the skilled artisan.

5       The ophthalmic formulations of the present invention are conveniently packaged in forms suitable for metered application, such as in containers equipped with a dropper, to facilitate the application to the eye. Containers suitable for dropwise application are usually made of suitable inert, non-toxic plastic material, and generally contain between  
10       about 0.5 and about 15 ml solution.

      The invention is further illustrated by the following non-limiting Examples, which are summarized in the reaction schemes of Figures 1 through 5, wherein the compounds are identified by the same designator in both the Examples and the Figures.

15

#### Example 1

7-[3 $\alpha$ , 5 $\alpha$ -Dihydroxy-2-(3 $\alpha$ -hydroxy-5-(5-(2-cyano)thienyl)-1E-pentenyl)cyclopentyl]-5Z-heptenoic acid (5a)

20

#### Step 1: Preparation of enone (2a)

      To a suspension of sodium hydride (26 mg, 1.14 mmol) in tetrahydrofuran (THF) (2.1 mL) cooled to 0° C was added dimethyl 4-(5-  
25       (2-cyano)thienyl)-2-oxobutylphosphonate (325 mg, 1.14 mmol) in THF (2.1 mL). After 15 minutes a solution of aldehyde 1 (500 mg, 1.03 mmol) in THF (3.0 mL) was added and the reaction solution was allowed to slowly warm to 23°C over a period of 8h. The reaction was quenched with saturated aqueous NH<sub>4</sub>Cl and extracted with ethylacetate (EtOAc).  
30       The combined organics were washed with brine, dried over MgSO<sub>4</sub>, filtered and concentrated *in vacuo*. Purification by flash column

chromatography (FCC) (silica gel, 3:1 hexane/EtOAc) provided 231 mg (37%) of enone 2a.

Step 2: Preparation of  $\alpha$ -alcohol (3a)

5

Sodium tetrahydridoborate (15 mg, 0.40 mmol) was added to a solution of enone 2a (231 mg, 0.38 mmol) in MeOH (3.0 mL) at 0° C. After 1h the solvent was removed *in vacuo* and the residue was stirred with 1N NaOH and EtOAc for 0.5h. The resultant mixture was extracted twice  
10 with EtOAc. The combined organic portions were washed with brine, dried over MgSO<sub>4</sub>, filtered and concentrated *in vacuo*. Purification of the residue by flash column chromatography (silica gel, 2:1 hexane/EtOAc) afforded 66 mg (29%) of pure  $\alpha$ -alcohol 3a.

15

Step 3: Preparation of trihydroxy ester (4b)

A solution of the  $\alpha$ -alcohol 3b (66 mg, 0.11 mmol) and pyridinium *p*-toluenesulfonate (33 mg, 0.13 mmol) in MeOH (1.0 mL) was stirred at 23° C for 12h. The solvent was removed *in vacuo*. The residue was  
20 diluted with EtOAc and then washed with 1N HCl, saturated aqueous NaHCO<sub>3</sub>, and brine. The organic portion was dried over MgSO<sub>4</sub>, filtered and concentrated *in vacuo*. Purification of the residue by flash column chromatography (silica gel, 100% EtOAc) gave 28 mg (59%) of trihydroxy ester 4b.

25

Step 4: Saponification of trihydroxy ester (4a)

Lithium hydroxide (0.3 mL of a 0.5 N solution in H<sub>2</sub>O, 0.15 mmol) was added to a solution of the trihydroxy ester 4a (28 mg, 0.081 mmol) in THF (0.6 mL) at 23 °C. After 16h the reaction mixture was acidified with 1N HCl and extracted with EtOAc. The organic portion was washed twice with brine, dried over Na<sub>2</sub>SO<sub>4</sub>, filtered and concentrated *in vacuo*. The residue was purified by flash column chromatography (silica gel, 9:1 CH<sub>2</sub>Cl<sub>2</sub>/MeOH) to afford 16 mg (60%) of the title compound 5a.

## Example 2

7-[3 $\alpha$ , 5 $\alpha$ -Dihydroxy-2-(3 $\alpha$ -hydroxy-5-(5-(2,3,4-trichloro)thienyl)-1E-pentenyl)cyclopentyl]-5Z-heptenoic acid (5b)

In accordance with the procedures described above for the synthesis of 5a, the use of dimethyl 4-(5-(2,3,4-triiodo)thienyl)-2-oxobutylphosphonate afforded 38 mg of free acid 5b.

## Example 3

7-[3 $\alpha$ , 5 $\alpha$ -Dihydroxy-2-(3 $\alpha$ -hydroxy-5-(5-(2,3-dichloro)thienyl)-1E-pentenyl)cyclopentyl]-5Z-heptenoic acid (5c)

In accordance with the procedures described above for the synthesis of 5a, the use of dimethyl 4-(5-(2,3-dichloro)thienyl)-2-oxobutylphosphonate afforded 10 mg of free acid 5c.



## Example 4

7-[3 $\alpha$ , 5 $\alpha$ -Dihydroxy-2-(3 $\alpha$ -hydroxy-5-(5-(2-iodo-4-methyl)thienyl)-1E-pentenyl)cyclopentyl]-5Z-heptenoic acid (5d)

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In accordance with the procedures described above for the synthesis of 5a, the use of dimethyl 4-(5-(2-iodo-4-methyl)thienyl)-2-oxobutylphosphonate afforded 22 mg of free acid 5d.

10

## Example 5

7-[3 $\alpha$ , 5 $\alpha$ -Dihydroxy-2-(3 $\alpha$ -hydroxy-5-(4-(3-bromo-2,5-dimethyl)thienyl)-1E-pentenyl)cyclopentyl]-5Z-heptenoic acid (5e)

15

In accordance with the procedures described above for the synthesis of 5a, the use of dimethyl 4-(4-(3-bromo-2,5-dimethyl)thienyl)-2-oxobutylphosphonate afforded 9 mg of free acid 5e.

## Example 6

20

7-[3 $\alpha$ , 5 $\alpha$ -Dihydroxy-2-(3 $\alpha$ -hydroxy-5-(3-(2,5-dichloro)thienyl)pentyl)-cyclopentyl]-5Z-heptenoic acid (5f)

Step 1: Preparation of enone (7)

25

To a suspension of sodium hydride (370 mg, 15.4 mmol) in tetrahydrofuran (THF) (12.0 mL) cooled to 0° C was added dimethyl 4-(3-(2,5-dichloro)thienyl)-2-oxobutyl-phosphonate (5.1 g, 15.4 mmol) in THF (8.0 mL). After 15 minutes a solution of aldehyde 6 (3.55 g, 14.0 mmol) in THF (5.0 mL) was added and the reaction solution was allowed to slowly

16

warm to 23° C over a period of 8h. The reaction was quenched with saturated aqueous NH<sub>4</sub>Cl and extracted with EtOAc. The combined organics were washed with brine, dried over MgSO<sub>4</sub>, filtered and concentrated *in vacuo*. Purification by flash column chromatography (silica gel, 3:1 hexane/EtOAc) provided 4.4 g (69%) of enone 7.

Step 2: Preparation of THP ether (8)

Sodium tetrahydridoborate (194 mg, 5.14 mmol) was added to a stirred solution of enone 7 (2.36 g, 5.14 mmol) in MeOH (10.3 mL) at 0° C. After 2h the solvent was removed *in vacuo* and the residue was diluted with saturated aqueous ammonium chloride and EtOAc. The organic portion was separated, washed with brine, dried (MgSO<sub>4</sub>), filtered and concentrated *in vacuo* to provide the corresponding allylic alcohol as a viscous oil.

A solution of the allylic alcohol and Wilkinson's catalyst (775 mg, 0.84 mmol) in THF (7.0 mL) was evacuated and purged under an atmosphere of hydrogen gas. After 12h the solvent was removed *in vacuo* and the residue was purified by FCC (silica gel, 3:1 hex/EtOAc) to furnish 824 mg (29%) of the corresponding dihydro alcohol.

The dihydro alcohol (prepared above), 3,4-dihydro-2H-pyran (1.4 mL, 15.4 mmol) and pyridinium *p*-toluenesulfonate (39 mg, 0.15 mmol) in CH<sub>2</sub>Cl<sub>2</sub> (3.1 mL) was stirred at 23° C for 12h. The reaction was diluted with EtOAc and washed with 1N HCl, saturated aq. NaHCO<sub>3</sub> and brine. The organic portion was dried (MgSO<sub>4</sub>), filtered and concentrated *in vacuo*. The residue was purified by FCC (silica gel, 3:1 hex EtOAc) to afford 727 mg (75%) of THP protected ether 8.

Step 3: Addition of  $\alpha$ -chain to 8:

Diisobutylaluminum hydride (0.86 mL of a 1.0 M solution in  $\text{CH}_2\text{Cl}_2$ , 0.86 mmol) was added to a solution of lactone 8 (313 mg, 0.57 mmol) in  $\text{CH}_2\text{Cl}_2$  (1.2 mL) at  $-78^\circ\text{C}$ . After 0.5h the reaction was quenched with saturated aqueous sodium potassium tartrate and allowed to warm to room temperature. The mixture was extracted with  $\text{CH}_2\text{Cl}_2$  and the organic portion was washed with brine, dried ( $\text{Na}_2\text{SO}_4$ ), filtered then concentrated *in vacuo* to provide the corresponding lactol as a clear, colorless oil.

To a suspension of (4-carboxybutyl)triphenylphosphonium bromide (800 mg, 1.80 mmol) in THF (7.2 mL) was added potassium bis(trimethylsilyl)amide (718 mg, 3.6 mmol) at  $0^\circ\text{C}$ . After 0.5h the reddish-orange mixture was cooled to  $-78^\circ\text{C}$  and a solution of the lactol (prepared above) in THF (3.0 mL) was added. The reaction mixture was allowed to warm to room temperature on its own accord. At this time it was quenched with saturated aqueous  $\text{NH}_4\text{Cl}$  and then extracted with EtOAc. The organic portion was washed with brine, dried ( $\text{MgSO}_4$ ), filtered and concentrated *in vacuo*. FCC (silica gel, 3:2 EtOAc/hex) afforded 180.5 mg (50 %) of free acid 10.

Step 4: Deprotection of bis-THP protected acid 10:

A solution of 10 (44 mg, 0.07 mmol) and pyridinium *p*-toluenesulfonate (21 mg, 0.084 mmol) in MeOH (1.0 mL) was stirred at  $23^\circ\text{C}$  for 12h. The solvent was removed *in vacuo*. The residue was diluted with EtOAc and then washed with 1N HCl, saturated aqueous  $\text{NaHCO}_3$ , and brine. The organic portion was dried over  $\text{MgSO}_4$ , filtered and concentrated *in vacuo*. Purification of the residue by flash column

18

chromatography (silica gel, 100% EtOAc) gave 15 mg (46%) of trihydroxy acid 5f.

#### Example 7

7-[3 $\alpha$ , 5 $\alpha$ -Dihydroxy-2-(3 $\alpha$ -hydroxy-5-(5-(2-cyano)thienyl)-1E-pentenyl)cyclopentyl]-5Z-heptenamide (11a)

Ammonia gas (~4.5 mL) was condensed at -78° C into a tube containing trihydroxy ester 4a (52 mg, 0.12 mmol) and ammonium chloride (192 mg, 3.56 mmol). The tube was then sealed and heated to 60 °C for 24 h. At this time the tube was cooled to -78 °C, vented and allowed to warm to room temperature on its own accord. The residue was dissolved in saturated aqueous NH<sub>4</sub>Cl and EtOAc. The organic portion was separated, dried over anhydrous MgSO<sub>4</sub>, filtered and the filtrate was concentrated *in vacuo*. The residue was purified by flash column chromatography (silica gel, 9:1 CH<sub>2</sub>Cl<sub>2</sub>/MeOH) to provide 15 mg (30%) of the title compound 11a.

#### Example 8

7-[3 $\alpha$ , 5 $\alpha$ -Dihydroxy-2-(3 $\alpha$ -hydroxy-5-(5-(2,3,4-trichloro)thienyl)-1E-pentenyl)cyclopentyl]-5Z-heptenamide (11b)

In accordance with the procedures described above for the synthesis of 11a, the use of trihydroxy ester 4b afforded 22 mg of amide 11b.

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## Example 9

7-[3 $\alpha$ , 5 $\alpha$ -Dihydroxy-2-(3 $\alpha$ -hydroxy-5-(5-(2,3-dichloro)thienyl)-1E-pentenyl)cyclopentyl]-5Z-heptenamide (11c)

5           In accordance with the procedures described above for the synthesis of 11a, the use of trihydroxy ester 4c afforded 6 mg of amide 11c.

## Example 10

10       7-[3 $\alpha$ , 5 $\alpha$ -Dihydroxy-2-(3 $\alpha$ -hydroxy-5-(5-(2-iodo-4-methyl)thienyl)-1E-pentenyl)cyclopentyl]-5Z-heptenamide (11d)

          In accordance with the procedures described above for the synthesis of 11a, the use of trihydroxy ester 4d afforded 6 mg of amide  
15       11d.

## Example 11

7-[3 $\alpha$ , 5 $\alpha$ -Dihydroxy-2-(3 $\alpha$ -hydroxy-5-(3-(2,5-dichloro)thienyl)-pentyl)cyclopentyl]-5Z-heptenamide (11f)

20

          A solution of free acid 10 (78 mg, 0.123 mmol), iodomethane (77 mL, 1.23 mmol) and 1,8-diazabicyclo[5.4.0]undec-7-ene (0.11 mL, 0.74 mmol) in acetone (1.0 mL) was stirred at 23 °C for 12h. The reaction mixture was concentrated *in vacuo* and the residue was purified by flash  
25       column chromatography (silica gel, 3:1 EtOAc/hexane) to yield 53 mg of the corresponding methyl ester.

          A solution of the methyl ester (53 mg, 0.082 mmol) and pyridinium *p*-toluenesulfonate (25 mg, 0.098 mmol) in MeOH (0.5 mL) was stirred at 23° C for 12h. The solvent was removed *in vacuo*. The residue was

diluted with EtOAc and then washed with 1N HCl, saturated aqueous NaHCO<sub>3</sub>, and brine. The organic portion was dried over MgSO<sub>4</sub>, filtered and concentrated *in vacuo*. Purification of the residue by flash chromatography (silica gel, 100% EtOAc) gave 28 mg of the  
5 corresponding trihydroxy ester.

Ammonia gas (~4.0 mL) was condensed at -78° C into a tube containing the trihydroxy ester (52 mg, 0.12 mmol) prepared above and ammonium chloride (122 mg, 2.28 mmol). The tube was then sealed and heated to 60° C for 72 h. At this time the tube was cooled to -78° C,  
10 vented and allowed to warm to room temperature on its own accord. The residue was dissolved in saturated aqueous NH<sub>4</sub>Cl and EtOAc. The organic portion was separated, dried over anhydrous MgSO<sub>4</sub>, filtered and the filtrate was concentrated *in vacuo*. The residue was purified by flash column chromatography (silica gel, 9:1 CH<sub>2</sub>Cl<sub>2</sub>/MeOH) to provide 17 mg  
15 (52%) of the title compound 11f.

### Example 12

N-2-Hydroxyethyl 7-[3 $\alpha$ , 5 $\alpha$ -dihydroxy-2-(3 $\alpha$ -hydroxy-5-(5-(3-bromo-2-methyl)thienyl)-1E-pentenyl)cyclopentyl]-5Z-heptenamide (11g)

20

A solution of trihydroxy ester 4g (36 mg, 0.742mmol) and 2-hydroxyethylamine (0.43 mL, 7.2 mmol) in MeOH (4.0 mL) was heated to 80° C for 48h. The reaction was cooled to room temperature and concentrated *in vacuo*. The residue was purified by FCC (silica gel, 9:1  
25 CH<sub>2</sub>Cl<sub>2</sub>/MeOH) to afford 35 mg (92%) of amide 11g.

21

## Example 13

N-Ethyl 7-[3 $\alpha$ , 5 $\alpha$ -dihydroxy-2-(3 $\alpha$ -hydroxy-5-(5-(3-bromo-2-methyl)thienyl)-1E-pentenyl)cyclopentyl]-5Z-heptenamide (11h)

5 In accordance with the procedures described above for the synthesis of 11g, the use of ethylamine afforded 25 mg (66%) of amide 11h.

## Example 14

10 N-2-Hydroxyethyl 7-[3 $\alpha$ , 5 $\alpha$ -dihydroxy-2-(3 $\alpha$ -hydroxy-5-(3-(2,5-dibromo)-thienyl)-1E-pentenyl)cyclopentyl]-5Z-heptenamide (11i)

In accordance with the procedures described above for the synthesis of 11g, the use of trihydroxy ester 4i afforded 30 mg (58%) of  
15 amide 11i.

## Example 15

N-Ethyl 7-[3 $\alpha$ , 5 $\alpha$ -dihydroxy-2-(3 $\alpha$ -hydroxy-5-(3-(2,5-dibromo)-thienyl)-1E-pentenyl)cyclopentyl]-5Z-heptenamide (11j)

20

In accordance with the procedures described above for the synthesis of 11h, the use of trihydroxy ester 4j afforded 30 mg (61%) of  
amide 11j.

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## Example 16

Isopropyl 7-[3 $\alpha$ , 5 $\alpha$ -Dihydroxy-2-(3 $\alpha$ -hydroxy-5-(5-(2-cyano)thienyl)-1E-pentenyl)cyclopentyl]-5Z-heptenoate (12a)

5           A solution of free acid 5a (38 mg, 0.090 mmol), 2-iodopropane (45 mL, 0.45 mmol) and 1,8-diazabicyclo[5.4.0]undec-7-ene (40 mL, 0.27 mmol) in acetone (0.18 mL) was stirred at 23 °C for 12h. The reaction mixture was concentrated *in vacuo* and the residue was purified by flash column chromatography (silica gel, 3:1 EtOAc/hexane) to yield 15 mg (36%) of  
10       the isopropyl ester 12a.

## Example 17

Isopropyl 7-[3 $\alpha$ , 5 $\alpha$ -Dihydroxy-2-(3 $\alpha$ -hydroxy-5-(5-(2,3,4-trichloro)-thienyl)-1E-pentenyl)cyclopentyl]-5Z-heptenoate (12b)

15           In accordance with the procedures described above for the synthesis of 12a, the use of free acid 5b afforded 12 mg (50%) of amide 12b.

## Example 18

20       Isopropyl 7-[3 $\alpha$ , 5 $\alpha$ -Dihydroxy-2-(3 $\alpha$ -hydroxy-5-(5-(3-bromo-2-methyl)-thienyl)-1E-pentenyl)cyclopentyl]-5Z-heptenoate (12k)

          In accordance with the procedures described above for the synthesis of 12a, the use of free acid 5k afforded 24 mg (56%) of amide  
25       12k.



## Example 19

Isopropyl 7-[3 $\alpha$ , 5 $\alpha$ -Dihydroxy-2-(3 $\alpha$ -hydroxy-5-(3-(2,5-dibromo)-thienyl)-1E-pentenyl)cyclopentyl]-5Z-heptenoate (12l)

5           In accordance with the procedures described above for the synthesis of 12a, the use of free acid 5l afforded 10 mg (14%) of amide 12l.

Certain of the above compounds were tested for activity in the various *in vitro* assays described below and the results are reported in the Table.

10           Activity at different prostanoid receptors was measured *in vitro* in isolated smooth muscle preparations. FP-activity was measured as contraction of the isolated feline iris sphincter. EP<sub>1</sub>-activity was measured as contraction of the longitudinal smooth muscle of the isolated guinea pig ileum. EP<sub>3</sub>-activity was measured as inhibition of the twitch  
15           response induced by electrical field stimulation in the isolated guinea pig was deferens and as contraction of the longitudinal smooth muscle of the isolated chick ileum. Activity was also measured as relaxation of smooth muscle of isolated rabbit jugular vein a preparation which appears to contain a unique PGF<sub>2 $\alpha$</sub> -sensitive receptor provisionally termed FPVASC.  
20           TP-vasoconstrictor activity was measured as contraction of rings of the isolated rat thoracic aorta. Effects on platelets from healthy human donors were measured by incubating platelet-rich plasma with the compounds described herein. Inhibition of aggregation was determined by the ability of the compounds described herein to inhibit platelet  
25           aggregation in platelet-rich plasma induced by 20  $\mu$ M ADP.

          In addition to stimulating the FP receptor associated with the cat iris, several examples also stimulated the EP<sub>3</sub> receptor. Compounds with agonist activity at EP<sub>3</sub> receptors may also be used for treating gastric or duodenal ulcer by virtue of their cytoprotective and anti-secretory  
30           properties. They may also be used as adjunctive therapy in combination with aspirin-like drugs and steroids to limit gastrointestinal side effects. EP<sub>3</sub> agonists stimulate uterine smooth muscle and may be used to terminate pregnancy in human females. EP<sub>3</sub> agonists are also useful in the cervical ripening process and could be used for inducing labor.

[illegible]

[illegible]

[illegible]

AGN.#

FP

EC<sub>50</sub> (nM)

IC<sub>25</sub>

FP/EP4

TP

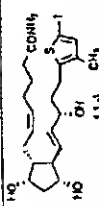
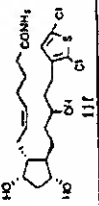

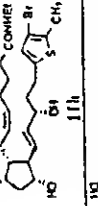
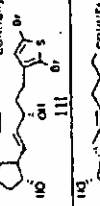

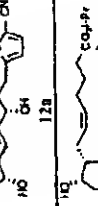
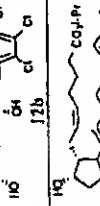
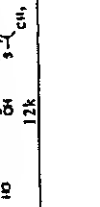
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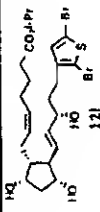
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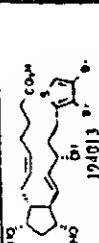
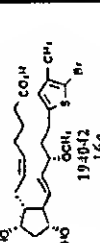
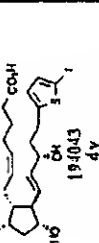
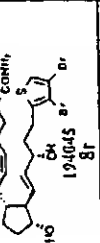
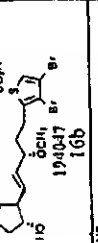


Monkey IOP

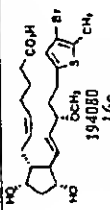
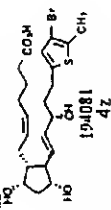
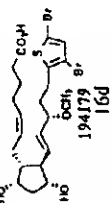
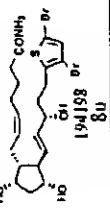
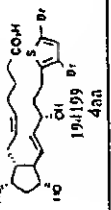
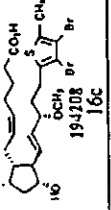
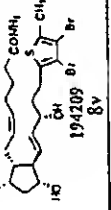
Hyp/

Miosis

AGN.#	FP	EC <sub>50</sub> (nM)	IC <sub>25</sub>	FP/EP4	TP	Platelets	Dog IOP	Monkey IOP	Hyp/
									
	8	NA			NA				
	38	NA							
	25	>> 10 <sup>4</sup>	>135,135	<0.0002	NA				
	48	NA	185,185	0.0003	NA				
	32	NA	82360	0.0004	NA				
	115								
	63								
	10	NA	NA						

AGN-#	FP	EP1	EC50 (nM)	IC25	FP/EP4	TP	Platelets	Dog IOP	Monkey IOP	Hyp/
			EP3 DP/EP2	EP4	Ratio		aggreg inhib	( 1 day )	( 5 day )	Miosis
	79					NA				

AGN-#	FP	EP1	EC <sub>50</sub> (nM) EP3 DP/EP2	IC <sub>25</sub> EP4	FP/EP4 Ratio	TP	Platelets aggreg inhib	Deg IOP (1 day)	Monkey IOP (5 day)	Hyp/ Miosis
 194013 4x	18	>>10 <sup>4</sup>		57	0.3					
 194042 16a	7.1			29685	0.0002	>10 <sup>4</sup>	NA			
 194043 4y	1.8	>10 <sup>4</sup> pa		335	0.005	2510		0.1%/-5.5		
 194045 8t	53			28090	0.002					
 194047 16b	60			824	0.07					
 194054 8s	8.6	NA		46200	0.0002	>10 <sup>4</sup>	NA	0.01%/-3.4 0.1%/-3.0		
 194079 8l	5.6	>>10 <sup>4</sup>		26393	0.0002	>10 <sup>4</sup>	NA	0.1%/-4.2		

AGN-#	FP	EP1	EC <sub>50</sub> (nM)	IC <sub>25</sub> EP4	FP/EP4 Ratio	TP	Platelets aggreg inhib	Dog IOP (1 day)	Monkey IOP (5 day)	Hyp/Miosis
 194080 16c	5.9	NA		133	0.04	NA				
 194081 4z	0.9	NA		25	0.04	4570				
 194179 16d	92			1070	0.09					
 194198 8u	12	NA		186490	0.00006	NA	NA	0.01%/-0.7 0.1%/-4.4		
 194199 4aa	5.9			16	0.4					
 194208 16c	288			1130	0.25					
 194209 8v	234			106655	0.02					



Other potential therapeutic applications are in osteoporosis, constipation, renal disorders, sexual dysfunction, baldness, diabetes, cancer and in disorder of immune regulation.

5 Many examples also have pronounced activity at the FP receptor, provisionally termed FPVASC associated with the vascular endothelium in the rabbit jugular vein preparation. Since such agents would be vasodilators they have potential in hypertension and any disease where tissue blood perfusion is compromised. Such indications include, but  
10 are not limited to, systemic hypertension, angina, stroke, retinal vascular diseases, claudication, Raynauds disease, diabetes, and pulmonary hypertension.

The compounds of the invention may also be useful in the treatment of various pathophysiological diseases including acute  
15 myocardial infarction, vascular thrombosis, hypertension, pulmonary hypertension, ischemic heart disease, congestive heart failure, and angina pectoris, in which case the compounds may be administered by any means that effect vasodilation and thereby relieve the symptoms of the disease. For example, administration may be by oral, transdermal,  
20 parenteral, subcutaneous, intravenous, intramuscular, intraperitoneal, transdermal, or buccal routes.

The compounds of the invention may be used alone, or in combination with other of the known vasodilator drugs.

The compounds of the invention may be formulated into an ointment containing about 0.10 to 10% of the active ingredient in a  
25 suitable base of, for example, white petrolatum, mineral oil and petroatum and lanolin alcohol. Other suitable bases will be readily apparent to those skilled in the art.

The pharmaceutical preparations of the present invention are  
30 manufactured in a manner which is itself known, for example, by means of conventional dissolving or suspending the compounds, which are all either water soluble or suspendable. For administration in the treatment of the other mentioned pathophysiological disorders. The pharmaceutical preparations which can be used orally include push-fit  
35 capsules made of gelatin, as well as soft, sealed capsules made of gelatin

and a plasticizer such as glycerol or sorbitol. The push-fit capsules can contain the active compounds in liquid form that may be mixed with fillers such as lactose, binders such as starches, and/or lubricants such as talc or magnesium stearate and, optionally, stabilizers. In soft capsules, the active compounds are preferably dissolved or suspended in suitable liquids, such as in buffered salt solution. In addition, stabilizers may be added.

In addition to being provided in a liquid form, for example in gelatin capsule or other suitable vehicle, the pharmaceutical preparations may contain suitable excipients to facilitate the processing of the active compounds into preparations that can be used pharmaceutically. Thus, pharmaceutical preparations for oral use can be obtained by adhering the solution of the active compounds to a solid support, optionally grinding the resulting mixture and processing the mixture of granules, after adding suitable auxiliaries, if desired or necessary, to obtain tablets or dragee cores.

Suitable excipients are, in particular, fillers such as sugars, for example lactose or sucrose, mannitol or sorbitol, cellulose preparations and/or calcium phosphates, for example tricalcium phosphate or calcium hydrogen phosphate, as well as binders such as starch, paste using for example, maize starch, wheat starch, rich starchy, potato starch, gelatin, tragacanth, methyl cellulose, hydroxypropylmethylcellulose, sodium carboxymethylcellulose, and/or polyvinyl pyrrolidone. If desired, disintegrating agents may be added such as the above-mentioned starches and also carboxymethyl-starch, crosslinked polyvinyl pyrrolidone, agar, or algenic acid or a salt thereof, such as sodium alginate. Auxiliaries are, above all, flow-regulating agents and lubricants, for example, silica, talc, stearic acid or salts thereof, such as magnesium stearate or calcium stearate, and/or polyethylene glycol. Dragee cores are provided with suitable coatings which if desired, are resistant to gastric juices. For this purpose, concentrated sugar solutions may be used, which may optionally containing gum arabic, talc, polyvinyl pyrrolidone, polyethylene glycol and/or titanium dioxide, lacquer solutions and suitable organic solvents or solvent mixtures. In order to produce coatings resistant to gastric

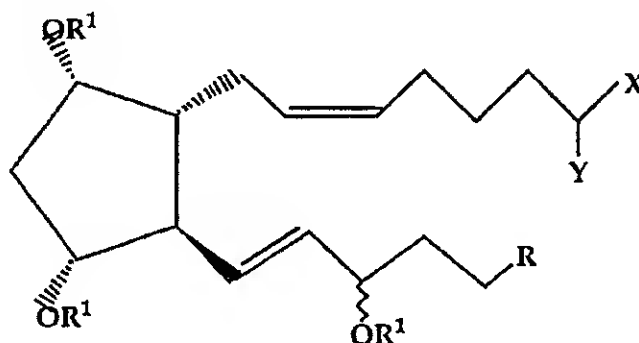
juices, solutions of suitable cellulose preparations such as acetylcellulose phthalate or hydroxypropylmethyl-cellulose phthalate, are used. Dye stuffs or pigments may be added to the tables or dragee coatings, for example, for identification or in order to characterize combinations of active compound doses.

Suitable formulations for intravenous or parenteral administration include aqueous solutions of the active compounds. In addition, suspensions of the active compounds as oily injection suspensions may be administered. Aqueous injection suspensions may contain substances which increase the viscosity of the suspension include, for example, sodium carboxymethyl cellulose, sorbitol, and/or dextran. Optionally, the suspension may also contain stabilizers.

The foregoing description details specific methods and compositions that can be employed to practice the present invention, and represents the best mode contemplated. However, it is apparent for one of ordinary skill in the art that further compounds with the desired pharmacological properties can be prepared in an analogous manner, and that the disclosed compounds can also be obtained from different starting compounds via different chemical reactions. Similarly, different pharmaceutical compositions may be prepared and used with substantially the same result. Thus, however detailed the foregoing may appear in text, it should not be construed as limiting the overall scope hereof; rather, the ambit of the present invention is to be governed only by the lawful construction of the appended claims.

## CLAIMS

1. A method of treating ocular hypertension which comprises administering to a mammal having ocular hypertension a therapeutically effective amount of a compound represented by formula I:

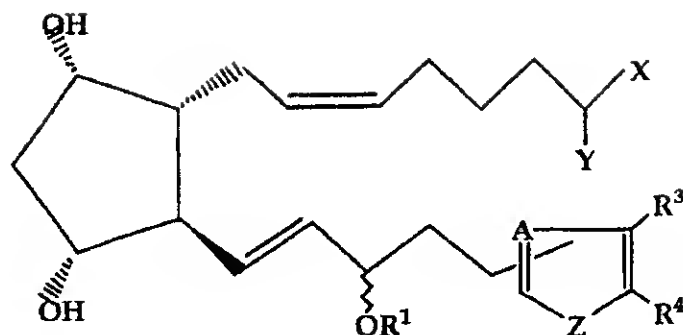


- wherein the hatched segments represent  $\alpha$  bonds, the solid triangle represents a  $\beta$  bond, wavy line attachments indicate either the alpha ( $\alpha$ ) or beta ( $\beta$ ) configuration; dashed bonds represent a double bond or a single bond, R is a substituted hetero aryl radical having at least two pendant substituents selected from the group consisting of  $C_1$  to  $C_6$  alkyl; halogen; trifluoromethyl;  $COR^1$ ;  $COCF_3$ ;  $SO_2NR^1$ ;  $NO_2$  and CN or at least one cyano group;  $R^1$  is hydrogen or a lower alkyl radical having up to six carbon atoms; X is selected from the group consisting of  $-OR^1$  and  $-N(R^1)_2$ ; Y is  $=O$  or represents 2 hydrogen radicals, and the 9, 11, or 15 alkyl esters thereof; provided, however, when said heteroaryl radical is a dichlorothieryl radical, said compound is not a 1-carboxylic acid or amide thereof.

2. The method of Claim 1 wherein the substituent on the heteroaryl radical is selected from the group consisting of  $C_1$  to  $C_6$  alkyl, chloro, bromo, iodo and CN.

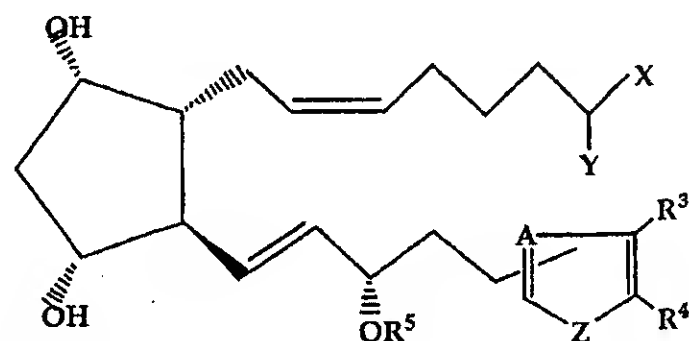
3. The method of Claim 1 wherein said compound is represented by formula II:

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wherein Z is selected from the group consisting of O and S, A is selected from the group consisting of C or CR<sup>2</sup>; R<sup>2</sup>, R<sup>3</sup> and R<sup>4</sup> are selected from the group consisting of hydrogen, halogen, cyano and lower alkyl having from 1 to 6 carbon atoms.

4. The method of claim 3 wherein said compound represented by formula III:



wherein R<sup>5</sup> is hydrogen.

5. The method of claim 4 wherein X is -OH or -NH<sub>2</sub>.
6. The method of claim 4 wherein Y is = O and X is -OH.
7. The method of claim 4 wherein Y is = O and X is -NH<sub>2</sub>.
8. The method of claim 4 wherein Z is S.

9. The method of claim 8 wherein at least one of  $R^2$ ,  $R^3$  and  $R^4$  are selected from the group consisting of cyano, chloro, bromo, iodo and methyl.
- 5 10. The method of claim 8 wherein at least one of  $R^2$ ,  $R^3$  and  $R^4$  is cyano.
- 10 11. The method of claim 8 wherein at least two of  $R^2$ ,  $R^3$  and  $R^4$  are chloro.
12. The method of claim 8 wherein at least two of  $R^2$ ,  $R^3$  and  $R^4$  are bromo.
- 15 13. The method of claim 8 wherein at least two of  $R^2$ ,  $R^3$  and  $R^4$  are methyl.
14. The method of claim 8 wherein at least one of  $R^2$ ,  $R^3$  and  $R^4$  is methyl and at least one of  $R^2$ ,  $R^3$  and  $R^4$  are chloro.
- 20 15. The method of claim 13 wherein at least one of  $R^2$ ,  $R^3$  or  $R^4$  are bromo and at least one of  $R^2$ ,  $R^3$  or  $R^4$  are methyl.
16. The method of claim 15 wherein said compound is selected from
- 25 the group consisting of
- 7-[3 $\alpha$ , 5 $\alpha$ -Dihydroxy-2-(3 $\alpha$ -hydroxy-5-(5-(2-cyano)thienyl)-1E-pentenyl)cyclopentyl]-5Z-heptenoic acid (5a)
- 30 7-[3 $\alpha$ , 5 $\alpha$ -Dihydroxy-2-(3 $\alpha$ -hydroxy-5-(5-(2,3,4-trichloro)thienyl)-1E-pentenyl)cyclopentyl]-5Z-heptenoic acid (5b)

- 7-[3 $\alpha$ , 5 $\alpha$ -Dihydroxy-2-(3 $\alpha$ -hydroxy-5-(5-(2,3-dichloro)thienyl)-1E-pentenyl)cyclopentyl]-5Z-heptenoic acid (5c)
- 5 7-[3 $\alpha$ , 5 $\alpha$ -Dihydroxy-2-(3 $\alpha$ -hydroxy-5-(5-(2-iodo-4-methyl)thienyl)-1E-pentenyl)cyclopentyl]-5Z-heptenoic acid (5d)
- 7-[3 $\alpha$ , 5 $\alpha$ -Dihydroxy-2-(3 $\alpha$ -hydroxy-5-(4-(3-bromo-2,5-dimethyl)thienyl)-1E-pentenyl)cyclopentyl]-5Z-heptenoic acid (5e)
- 10 7-[3 $\alpha$ , 5 $\alpha$ -Dihydroxy-2-(3 $\alpha$ -hydroxy-5-(3-(2,5-dichloro)thienyl)pentyl)-cyclopentyl]-5Z-heptenoic acid (5f)
- 7-[3 $\alpha$ , 5 $\alpha$ -Dihydroxy-2-(3 $\alpha$ -hydroxy-5-(5-(2-cyano)thienyl)-1E-pentenyl)cyclopentyl]-5Z-heptenamide (11a)
- 15 7-[3 $\alpha$ , 5 $\alpha$ -Dihydroxy-2-(3 $\alpha$ -hydroxy-5-(5-(2,3,4-trichloro)thienyl)-1E-pentenyl)cyclopentyl]-5Z-heptenamide (11b)
- 7-[3 $\alpha$ , 5 $\alpha$ -Dihydroxy-2-(3 $\alpha$ -hydroxy-5-(5-(2,3-dichloro)thienyl)-1E-pentenyl)cyclopentyl]-5Z-heptenamide (11c)
- 20 7-[3 $\alpha$ , 5 $\alpha$ -Dihydroxy-2-(3 $\alpha$ -hydroxy-5-(5-(2-iodo-4-methyl)thienyl)-1E-pentenyl)cyclopentyl]-5Z-heptenamide (11d)
- 7-[3 $\alpha$ , 5 $\alpha$ -Dihydroxy-2-(3 $\alpha$ -hydroxy-5-(3-(2,5-dichloro)thienyl)-pentyl)cyclopentyl]-5Z-heptenamide (11f)
- 25 N-2-Hydroxyethyl 7-[3 $\alpha$ , 5 $\alpha$ -dihydroxy-2-(3 $\alpha$ -hydroxy-5-(5-(3-bromo-2-methyl)thienyl)-1E-pentenyl)cyclopentyl]-5Z-heptenamide (11g)
- 30

N-Ethyl 7-[3 $\alpha$ , 5 $\alpha$ -dihydroxy-2-(3 $\alpha$ -hydroxy-5-(5-(3-bromo-2-methyl)thienyl)-1E-pentenyl)cyclopentyl]-5Z-heptenamide (11h)

5 N-2-Hydroxyethyl 7-[3 $\alpha$ , 5 $\alpha$ -dihydroxy-2-(3 $\alpha$ -hydroxy-5-(3-(2,5-dibromo)-thienyl)-1E-pentenyl)cyclopentyl]-5Z-heptenamide (11i)

N-Ethyl 7-[3 $\alpha$ , 5 $\alpha$ -dihydroxy-2-(3 $\alpha$ -hydroxy-5-(3-(2,5-dibromo)-thienyl)-1E-pentenyl)cyclopentyl]-5Z-heptenamide (11j)

10 Isopropyl 7-[3 $\alpha$ , 5 $\alpha$ -Dihydroxy-2-(3 $\alpha$ -hydroxy-5-(5-(2-cyano)thienyl)-1E-pentenyl)cyclopentyl]-5Z-heptenoate (12a)

15 Isopropyl 7-[3 $\alpha$ , 5 $\alpha$ -Dihydroxy-2-(3 $\alpha$ -hydroxy-5-(5-(2,3,4-trichloro)-thienyl)-1E-pentenyl)cyclopentyl]-5Z-heptenoate (12b)

Isopropyl 7-[3 $\alpha$ , 5 $\alpha$ -Dihydroxy-2-(3 $\alpha$ -hydroxy-5-(5-(3-bromo-2-methyl)-thienyl)-1E-pentenyl)cyclopentyl]-5Z-heptenoate (12k)

20 Isopropyl 7-[3 $\alpha$ , 5 $\alpha$ -Dihydroxy-2-(3 $\alpha$ -hydroxy-5-(3-(2,5-dibromo)-thienyl)-1E-pentenyl)cyclopentyl]-5Z-heptenoate (12l)

25 17. An ophthalmic solution comprising a therapeutically effective amount of a compound of formula I, as defined in Claim 1, or a pharmaceutically acceptable salt thereof, in admixture with a non-toxic, ophthalmically acceptable liquid vehicle, packaged in a container suitable for metered application.

18. The ophthalmic solution of Claim 17 wherein said compound is a compound of Formula III.

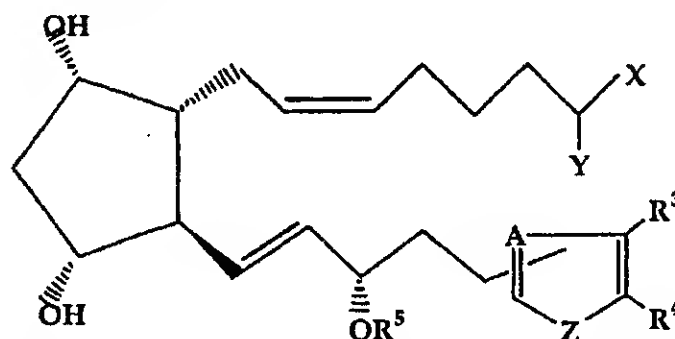
30 19. A pharmaceutical product, comprising a container adapted to dispense the contents of said container in metered form; and an



ophthalmic solution in said container comprising a compound of formula I as defined in Claim 1, or a pharmaceutically acceptable salt thereof, in admixture with a non-toxic, ophthalmically acceptable liquid vehicle.

20. The product of claim 19 wherein said compound is a compound of Formula III.

21. The compound represented by Formula III:



wherein the hatched segments represent  $\alpha$  bonds, the solid triangle represents a  $\beta$  bond; the dashed bond represents a double bond or a single bond;  $R^5$  represents hydrogen or a lower alkyl radical having up to six carbon atoms; X is selected from the group consisting of  $-OR^1$  and  $-N(R^1)_2$ ; Y is  $=O$  or represents 2 hydrogen radicals;  $R^1$  is hydrogen or a lower alkyl radical having up to six carbon atoms; and the 9, 11, or 15 alkyl esters thereof; provided, however, when said heteroaryl radical is a dichlorothienyl radical, said compound is not a 1-carboxylic acid or amide thereof.

22. A compound according to claim 21 wherein Z is S.

23. The compound of claim 22 wherein at least one of  $R^2$ ,  $R^3$  and  $R^4$ , are selected from the group consisting of cyano, chloro, bromo, iodo and methyl.

24. The compound of claim 23 wherein at least one of R<sup>2</sup>, R<sup>3</sup> and R<sup>4</sup> is cyano.
25. The compound of claim 23 wherein at least two of R<sup>2</sup>, R<sup>3</sup> and R<sup>4</sup> are chloro.
26. The compound of claim 23 wherein at least two of R<sup>2</sup>, R<sup>3</sup> and R<sup>4</sup> are bromo.
27. The compound of claim 23 wherein at least two of R<sup>2</sup>, R<sup>3</sup> and R<sup>4</sup> are methyl.
28. The compound of claim 23 wherein at least one of R<sup>2</sup>, R<sup>3</sup> and R<sup>4</sup> is methyl and at least one of R<sup>2</sup>, R<sup>3</sup> and R<sup>4</sup> are chloro.
29. The compound of claim 23 wherein at least one of R<sup>2</sup>, R<sup>3</sup> or R<sup>4</sup> are bromo and at least one of R<sup>2</sup>, R<sup>3</sup> or R<sup>4</sup> are methyl.
- 7-[3 $\alpha$ , 5 $\alpha$ -Dihydroxy-2-(3 $\alpha$ -hydroxy-5-(5-(2-cyano)thienyl)-1E-pentenyl)cyclopentyl]-5Z-heptenoic acid (5a)
- 7-[3 $\alpha$ , 5 $\alpha$ -Dihydroxy-2-(3 $\alpha$ -hydroxy-5-(5-(2,3,4-trichloro)thienyl)-1E-pentenyl)cyclopentyl]-5Z-heptenoic acid (5b)
- 7-[3 $\alpha$ , 5 $\alpha$ -Dihydroxy-2-(3 $\alpha$ -hydroxy-5-(5-(2,3-dichloro)thienyl)-1E-pentenyl)cyclopentyl]-5Z-heptenoic acid (5c)
- 7-[3 $\alpha$ , 5 $\alpha$ -Dihydroxy-2-(3 $\alpha$ -hydroxy-5-(5-(2-iodo-4-methyl)thienyl)-1E-pentenyl)cyclopentyl]-5Z-heptenoic acid (5d)
- 7-[3 $\alpha$ , 5 $\alpha$ -Dihydroxy-2-(3 $\alpha$ -hydroxy-5-(4-(3-bromo-2,5-dimethyl)thienyl)-1E-pentenyl)cyclopentyl]-5Z-heptenoic acid (5e)

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7-[3 $\alpha$ , 5 $\alpha$ -Dihydroxy-2-(3 $\alpha$ -hydroxy-5-(3-(2,5-dichloro)thienyl)pentyl)-  
cyclopentyl]-5Z-heptenoic acid (5f)

5 7-[3 $\alpha$ , 5 $\alpha$ -Dihydroxy-2-(3 $\alpha$ -hydroxy-5-(5-(2-cyano)thienyl)-1E-  
pentenyl)cyclopentyl]-5Z-heptenamide (11a)

7-[3 $\alpha$ , 5 $\alpha$ -Dihydroxy-2-(3 $\alpha$ -hydroxy-5-(5-(2,3,4-trichloro)thienyl)-1E-  
pentenyl)cyclopentyl]-5Z-heptenamide (11b)

10 7-[3 $\alpha$ , 5 $\alpha$ -Dihydroxy-2-(3 $\alpha$ -hydroxy-5-(5-(2,3-dichloro)thienyl)-1E-  
pentenyl)cyclopentyl]-5Z-heptenamide (11c)

15 7-[3 $\alpha$ , 5 $\alpha$ -Dihydroxy-2-(3 $\alpha$ -hydroxy-5-(5-(2-iodo-4-methyl)thienyl)-1E-  
pentenyl)cyclopentyl]-5Z-heptenamide (11d)

7-[3 $\alpha$ , 5 $\alpha$ -Dihydroxy-2-(3 $\alpha$ -hydroxy-5-(3-(2,5-dichloro)thienyl)-  
pentyl)cyclopentyl]-5Z-heptenamide (11f)

20 N-2-Hydroxyethyl 7-[3 $\alpha$ , 5 $\alpha$ -dihydroxy-2-(3 $\alpha$ -hydroxy-5-(5-(3-bromo-2-  
methyl)thienyl)-1E-pentenyl)cyclopentyl]-5Z-heptenamide (11g)

N-Ethyl 7-[3 $\alpha$ , 5 $\alpha$ -dihydroxy-2-(3 $\alpha$ -hydroxy-5-(5-(3-bromo-2-  
methyl)thienyl)-1E-pentenyl)cyclopentyl]-5Z-heptenamide (11h)

25 N-2-Hydroxyethyl 7-[3 $\alpha$ , 5 $\alpha$ -dihydroxy-2-(3 $\alpha$ -hydroxy-5-(3-(2,5-  
dibromo)-thienyl)-1E-pentenyl)cyclopentyl]-5Z-heptenamide (11i)

N-Ethyl 7-[3 $\alpha$ , 5 $\alpha$ -dihydroxy-2-(3 $\alpha$ -hydroxy-5-(3-(2,5-dibromo)-thienyl)-  
1E-pentenyl)cyclopentyl]-5Z-heptenamide (11j)

30

Isopropyl 7-[3 $\alpha$ , 5 $\alpha$ -Dihydroxy-2-(3 $\alpha$ -hydroxy-5-(5-(2-cyano)thienyl)-1E-pentenyl)cyclopentyl]-5Z-heptenoate (12a)

5 Isopropyl 7-[3 $\alpha$ , 5 $\alpha$ -Dihydroxy-2-(3 $\alpha$ -hydroxy-5-(5-(2,3,4-trichloro)-thienyl)-1E-pentenyl)cyclopentyl]-5Z-heptenoate (12b)

Isopropyl 7-[3 $\alpha$ , 5 $\alpha$ -Dihydroxy-2-(3 $\alpha$ -hydroxy-5-(5-(3-bromo-2-methyl)-thienyl)-1E-pentenyl)cyclopentyl]-5Z-heptenoate (12k)

10 Isopropyl 7-[3 $\alpha$ , 5 $\alpha$ -Dihydroxy-2-(3 $\alpha$ -hydroxy-5-(3-(2,5-dibromo)-thienyl)-1E-pentenyl)cyclopentyl]-5Z-heptenoate (12l)

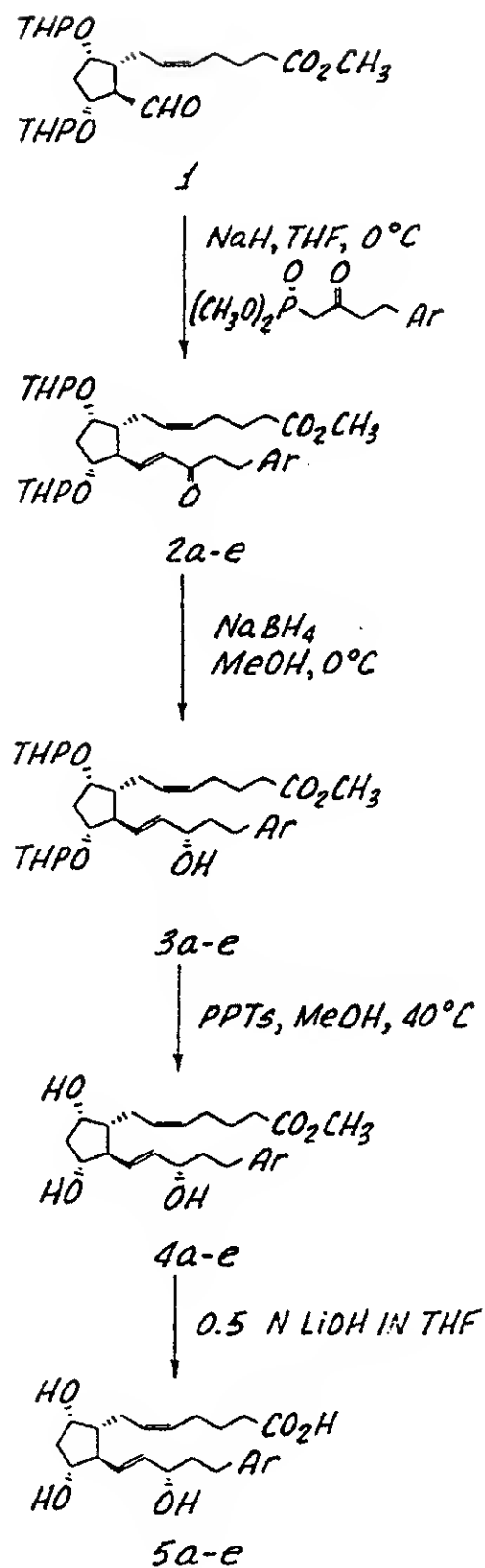
Fig. 1.

FIG. 2.

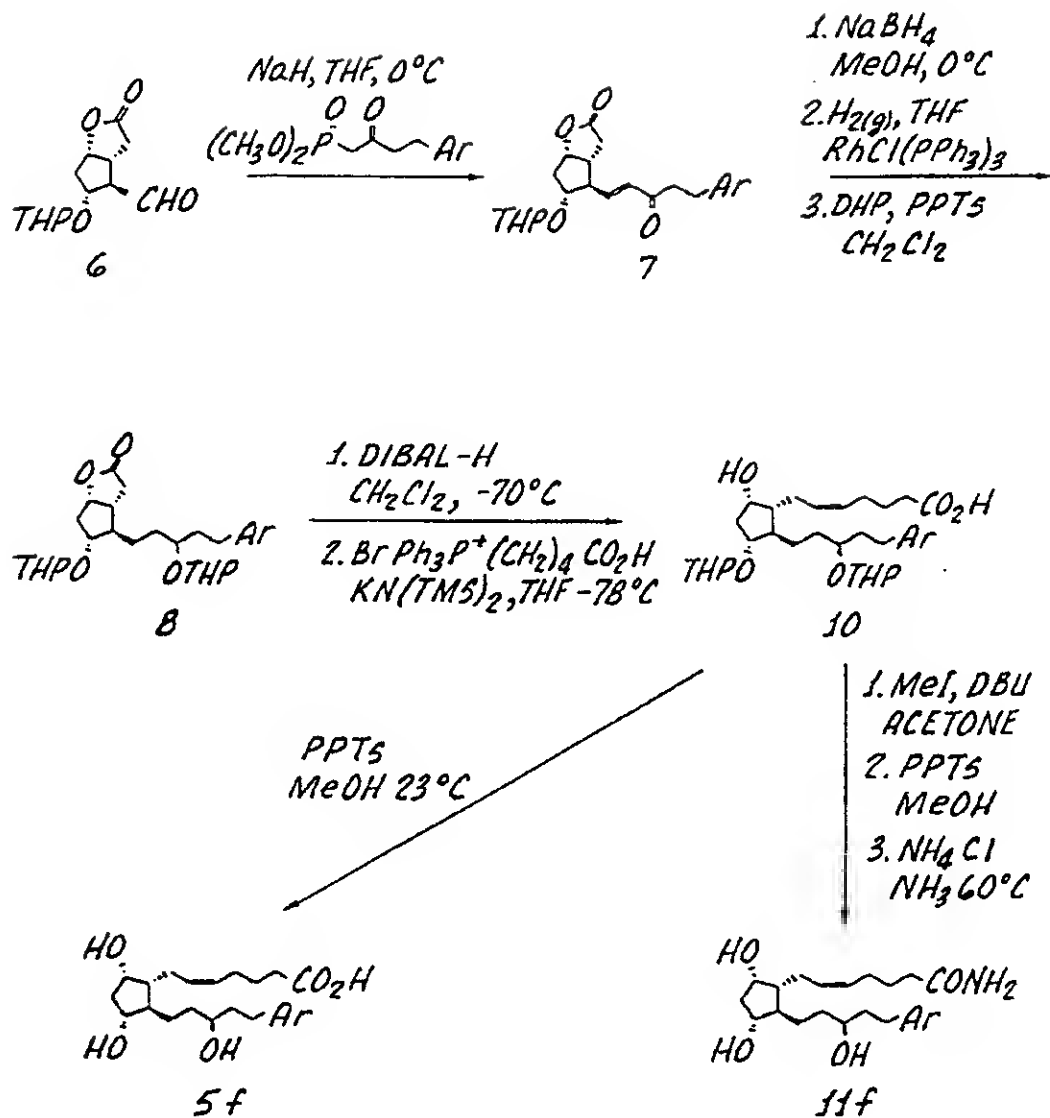
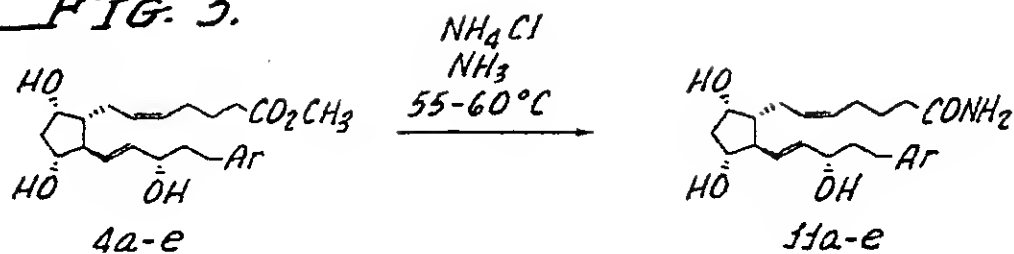
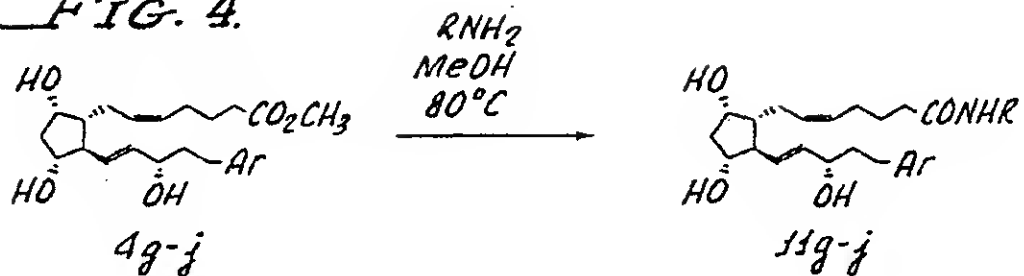
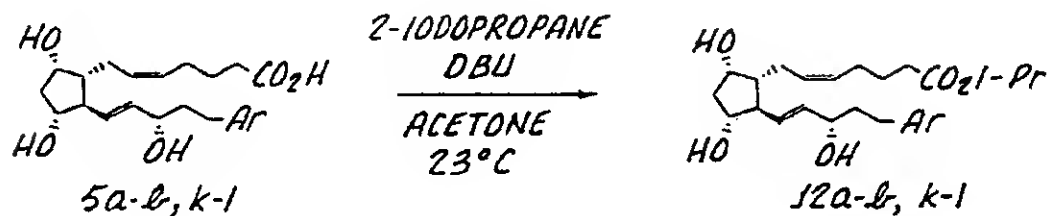


FIG. 3.FIG. 4.FIG. 5.

# INTERNATIONAL SEARCH REPORT

Int. Patent Application No

PCT/US 98/24481

**A. CLASSIFICATION OF SUBJECT MATTER**  
IPC 6 A61K31/557 C07D277/30

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 A61K C07C C07D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 97 31895 A (ALLERGAN INC) 4 September 1997  see claims 11-13, 27, 28 see Table I Page 20, 20A compounds 5b, 5d, 6b, 6d, 5e, 6e ---	1-3, 17, 19, 21-23, 26, 29
X	WO 96 36599 A (ALLERGAN INC) 21 November 1996 see claims 16, 18-20, 29, 30 ---	1-6, 8, 9, 17-20
X, P	US 5 834 498 A (BURK ROBERT M) 10 November 1998 cited in the application see column 15 - column 22 -----	1-29

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search

15 February 1999

Date of mailing of the international search report

19/02/1999

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2  
NL - 2280 HV Rijswijk  
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,  
Fax: (+31-70) 340-3016

Authorized officer

Trifilieff-Riolo, S



# INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/US 98/24481

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